

Frontal Dynamics in the South China Sea

Glen Gawarkiewicz
Mail Stop #21
Woods Hole Oceanographic Institution
Woods Hole, MA 02543
Phone: (508) 289-2913 Fax: (508) 457-2181 Email: gleng@whoi.edu

Kenneth Brink
Mail Stop #21
Woods Hole Oceanographic Institution
Woods Hole, MA 02543
Phone: (508) 289-2535 Fax: (508) 457-2181 Email: kbrink@whoi.edu

David C. Chapman
Mail Stop #21
Woods Hole Oceanographic Institution
Woods Hole, MA 02543
Phone: (508) 289-2792 Fax: (508) 457-2181 Email: dchapman@whoi.edu

Robert Beardsley
Mail Stop #21
Woods Hole Oceanographic Institution
Woods Hole, MA 02543
Phone: (508) 289-2536 Fax: (508) 457-2181 Email: rbeardsley@whoi.edu

Award Number: N00014-1-01-0210
<http://www.asiaex.edu>

LONG-TERM GOALS

Our long-term goal is to understand the dynamics of oceanographic processes which contribute to variability of the currents and thermohaline structure in the shelf/slope region of the South China Sea.

OBJECTIVES

The primary objectives of this study are to determine the primary processes contributing to variability in the shelf/slope region of the northern South China Sea, and to assess and improve the capability of numerical models of the region. We have been studying the role of the winter monsoon in the inter-annual variability of the Kuroshio Intrusion into the South China Sea, the dynamics of the barotropic and baroclinic tides near the shelfbreak, and the effect of different forcing mechanisms (wind, open boundaries, data assimilation) on the circulation in the NRL-Stennis numerical model of the region.

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE 30 SEP 2003		2. REPORT TYPE		3. DATES COVERED 00-00-2003 to 00-00-2003	
4. TITLE AND SUBTITLE Frontal Dynamics in the South China Sea				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Woods Hole Oceanographic Institution,,Woods Hole,,MA, 02543				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT Our long-term goal is to understand the dynamics of oceanographic processes which contribute to variability of the currents and thermohaline structure in the shelf/slope region of the South China Sea.					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

APPROACH

We have been using the data collected during the ASIAEX South China Sea field program to examine the inter-annual variability of the wind forcing and its effect on the circulation in the northern South China Sea. There were substantial differences in the circulation between spring 2000 and 2001, including the presence of a Kuroshio Intrusion in the first year but not the second. There were also differences in the mean stratification. We have examined the tidal dynamics in spring 2001, when the intensive mooring array was deployed, and have also collected additional hydrographic data from spring 2003 which is presently being analyzed.

WORK COMPLETED

We have finished initial studies on the thermohaline and velocity structure near the shelfbreak and the associated circulation over the deep basin from spring 2000 and 2001 (Gawarkiewicz et al., 2003), on the barotropic tides over the outer shelf and upper slope (Beardsley et al., 2003), on the sensitivity of the circulation to different forcing mechanisms in a numerical model (Chapman et al., 2003), and on the day to day variability of internal solitary waves and internal tides (Duda et al., 2003).

RESULTS

The mesoscale circulation near the shelfbreak was remarkably different between 2000 and 2001. In 2000, there was a strong anti-cyclonic circulation which drove a northeastward flow of more than 100 cm/s to the northeast. The water mass properties suggest that a strong Kuroshio Intrusion had developed in January, and was persistent for several months. In contrast, in 2001 there was a weak cyclonic circulation, and the slope flow was to the southwest at 20 cm/s. Maps of dynamic height clearly indicate the differences between the two years, with dynamic height gradients suggesting a strong onshore flow in 2000 directed toward the ASIAEX study area, with a much broader and weaker onshore flow in 2001 directed eastward of the study area (Figure 1). The primary differences in the wind stress curl occurred in the late fall and early winter (Figure 2). Analysis of the ADCP data versus the inferred surface velocities from sea surface height gradients suggest that the alongslope flow was substantially underestimated. Stability characteristics of the slope current are estimated, and suggest a most unstable wavelength of 106 km and a growth rate of approximately one day, due to the large Rossby number of the flow. The correlation scales for temperature in the upper 150 m of the water column were quite short in both years, between 5 and 10 km depending on depth. This is much shorter than the baroclinic Rossby radius, suggesting that the correlation scales are set by internal tides or processes other than frontal instabilities.

Chapman et al. (2003) examined the model fields from the Northern South China Sea Nowcast/Forecast System developed by D.-S. Ko and R. Preller of NRL-Stennis. The large scale circulation features in spring of the two years 2000 and 2001 are similar to the observed field in the sense that spring in 2000 is dominated by an anti-cyclonic circulation while spring 2001 is dominated by the larger scale cyclonic circulation more typical of the summer. The flow fields in the model are highly surface trapped due to the primary forcing mechanisms, namely wind stress and inflow of Kuroshio water. The most important forcing mechanisms were the strength of the wind stress curl near Luzon Strait and the open boundary condition at Luzon Strait (i.e. Kuroshio inflow into the South China Sea). Analysis of the kinetic energy within the model shows the assimilation of sea surface

height data into the model actually acts to damp kinetic energy within the model, reducing the spindown time.

The barotropic tides over the slope are dominated by the O_1 and K_1 diurnal tides, while over the shelf is dominated by the M_2 semi-diurnal tide (Beardsley et al., 2003). The tidal energy flux is primarily westward over the slope but is relatively small for the diurnal components. The tidal energy flux over the shelf is aligned with the transport. Despite refraction and topographic steering, the tidal wave is conserving energy as it propagates onshore, explaining its dominance in the shallow water. The baroclinic tides have also been examined (Duda et al., 2003). The diurnal tide is dominant, and is sufficiently nonlinear to break down into shoreward propagating internal bores at times.

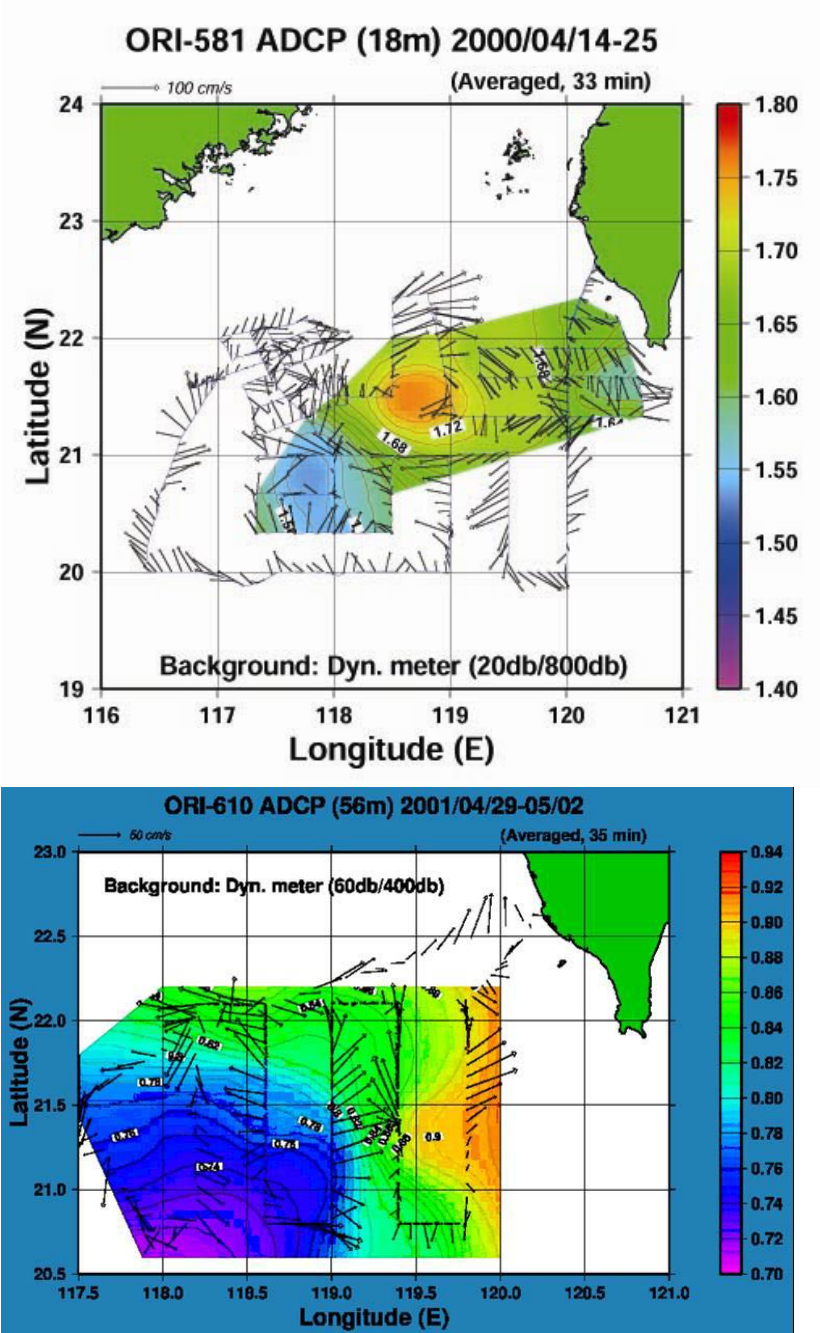


Figure 1- Dynamic height fields over the central basins for spring 2000 and 2001.

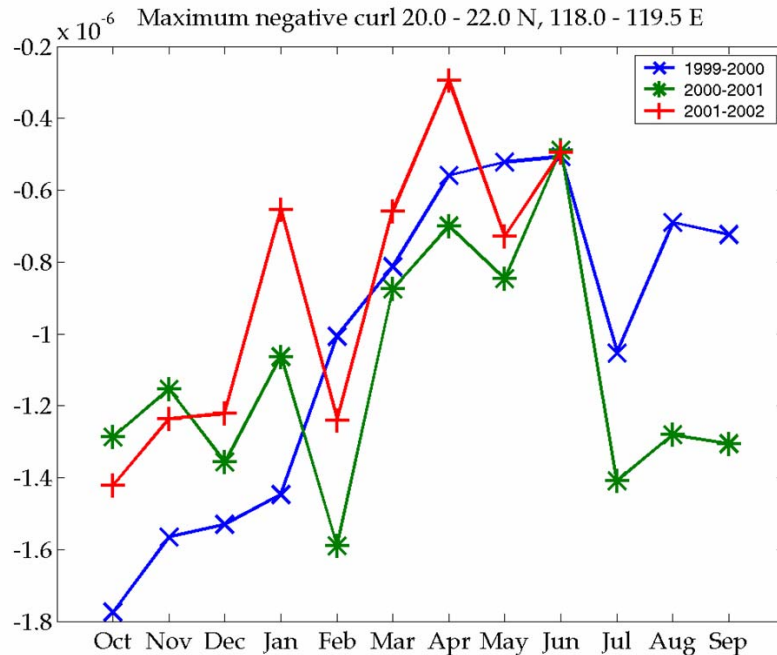


Figure 2- Maximum wind stress curl for three years. The strongest curl was in the autumn and early winter of 1999-2000, preceding the large Kuroshio Intrusion event of 2000.

IMPACT/APPLICATIONS

The results we have obtained are the first high resolution observations of the thermohaline circulation near the shelfbreak in the South China Sea. This work is essential to understanding the spatial and temporal scales of variability near the shelfbreak, which is a necessary element in understanding acoustic propagation in this region. We have quantified the cross-slope structure of a Kuroshio Intrusion and established the important dynamical parameters, such as the Rossby, Richardson, and Burger numbers for the strong slope flow, as well as establishing the duration of the intrusion. The work on the baroclinic and barotropic tides will be useful in determining the role of oceanographic processes in different frequency bands to the variability of sound transmission loss over the shelf and slope in this region. The analysis of the numerical model will help in the choice and application of data assimilation into the South China Sea Nowcast/Forecast model.

RELATED PROJECTS

This work is strongly related to the ONR program on “Capturing Uncertainty in the Tactical Environment.” We will be using quantitative results on the oceanographic processes resolved in this experiment to continue the probability density function approach to sonar system performance. The work on internal tides and internal waves are also relevant to the ONR program “Effects of Sound in the Marine Environment”. We are trying to quantify the impact of processes which are not resolved in the ESME Risk Assessment model on transmission loss over the shelf and slope.

PUBLICATIONS

Beardsley, R., T. Duda, J. Lynch, S. Ramp, J. Irish, C.-S. Chiu, T. Y. Tang, and Y. J. Yang, 2003. The barotropic tide in the Northeast South China Sea. *IEEE J. of Oceanic Engineering* [refereed].

Chapman, D. C., D.-S. Ko, and R. Preller, 2003. A high resolution numerical modeling study of the subtidal circulation in the northern South China Sea. *IEEE J. of Oceanic Engineering* [refereed].

Duda, T., J. Lynch, J. Irish, R. Beardsley, S. Ramp, C.-S. Chiu, T. Y. Tang, and Y. J. Yang, 2003. Internal tide and nonlinear internal tide behavior at the continental slope in the northern South China Sea. *IEEE J. of Oceanic Engineering* [refereed].

Gawarkiewicz, G., J. Wang, M. Caruso, K. Brink, F. Bahr, and S. Ramp, 2003. Shelfbreak circulation and thermohaline structure in the northern South China Sea: Contrasting spring 2000 and 2001. *IEEE J. of Oceanic Engineering* [refereed].